# The Impact of Agricultural Growth on Employment in Rwanda: A Three-Sector Model

## Agricultural Policy Development Project
## Research Report No. 14

Abt Associates Inc.

Cambridge, MA
Lexington, MA
Hadley, MA
Bethesda, MD
Washington, DC
Chicago, IL
Cairo, Egypt
Johannesburg, South Africa

August 2002

*Prepared for*
United States Agency for International Development/Rwanda
B.P. 2848
Kigali, Rwanda


Abt Associates Inc.
Suite 600
4800 Montgomery Lane
Bethesda, MD  20814-5341

*Prepared by*
John W. Mellor
Chandrashekhar Ranade

*Title*
**The Impact of Agricultural Growth on Employment in Rwanda: A Three-Sector Model**
*Author(s)*
**John W. Mellor and Chandrashekhar Ranade**
*Date*
**August 2002**

*Contract Number*
**PCE-I-00-99-00033-00**
*Task Number*
**800**
*Cognizant Technical Officer*
**Andy Karas**
*Strategic Objective:*
**Strategic Objective #3: Increased Ability of Rural Families in Targeted Communities to Improve Household Food Security**

*Contractor*
**Abt Associates Inc.**
**4800 Montgomery Avenue**
**Hampden Square, Suite 600**
**Bethesda, MD 20814**
**Tel: (301) 913-0500**
**Fax: (301) 652-3618**

This report was made possible through support provided by the Office of Economic Growth, Agriculture and Trade, Global Bureau, U.S. Agency for International Development, under the terms of Contract No. PCE-I-00-99-00033-00. The opinions expressed herein are those of the author(s) and do not necessarily reflect the views of the U.S. Agency for International Development.

*Acknowledgements*

It would not have been possible to do this work without the encouragement and active assistance of Minister of Agriculture, Ephraim Kabaija. Throughout this effort, he showed his commitment to the intensification and commercialization of Rwanda's agriculture as the core of the development effort. That is the basis for this work.

My contribution to this paper arose from several trips to Rwanda. Andy Cook provided the continuity and follow-up essential to completing this work as well as serving as a constant critic and source of ideas. I am most grateful to him. Jean Pierre Rucakibungo was a vital source of data and perspective. Andy Karas was of continuous help, not only in solving various bureaucratic problems, but also on various substantive issues of conceptualization and data. We are especially grateful to him. Similarly, Richard Goldman reviewed many of the ideas and provided useful suggestions. Karen Christensen was an important source of data and also offered a critique of their use. Several seminars at USAID, the Ministry of Agriculture, and the World Bank were of great help. Thanks to the many participants for their suggestions and active interaction. Dean De Rosa gave an early draft a careful reading and made several suggestions including particularly useful ones with respect to the real exchange rate. Sara Piccicuto gave the manuscript a careful reading which yielded a detailed editing and numerous helpful suggestions.

# Table of Contents

# Preface

The model presented here attempts to measure the ability of agricultural growth to generate employment in Rwanda. It constitutes an alternate approach to the one discussed in APD Research Report No. 13, entitled "How Much Employment Can Rapid Agricultural Growth Generate? – Sectoral Polic ies for Maximum Impact in Rwanda" (Mellor 2002a). That paper (referred to as the 'basic paper') states a strategy for achieving rapid agricultural growth, calculates the input and commodity composition of a high growth rate in agriculture, and provides details of the strategy for achieving a high growth rate.[1] The basic paper takes a high agricultural growth rate as given and calculates the impact of that growth on employment.

Consistent with a large literature on the subject, both the model and approach taken in the basic paper emphasize the indirect effects of agricultural growth on employment. That is, they highlight the effect of increased demand generated by agricultural growth for the products of the employment-intensive, rural, non-farm sector. We compare that effect with the impact of urban, formal-sector growth on employment.

The basic paper assumes a perfectly elastic supply of labor and, therefore, that there is no restraint from rising wages, and hence rising prices on growth of the non-tradable sector. That assumption is consistent with the full employment of labor, but also with the potential to increase the productivity of labor. The approach of the basic paper is static; in other words, it does not allow for simultaneity, or for transfer of resources from one sector to another.

The model presented here, however, takes an alternative approach to calculating the impact of agricultural growth on employment. Instead of a growth accounting framework, it formulates a three-sector model with Cobb-Douglas production functions. The objective is the same in the two papers; Namely, it seeks to measure the impact of agricultural growth on employment with emphasis on the impact generated by increased demand for the products of the employment-intensive, rural, non-farm sector. The three-sector model formulated, has all the usual assumptions of a neo-classical model. Those assumptions are similar to those implicit in IMF and World Bank recommendations. That is, that all resources, including labor, are fully employed, perfect knowledge of all relevant economic variables, complete mobility of factors of production, and completely open international markets for tradable commodities.

Those assumptions are not as unreasonable as they may seem at first glance. The most glaring apparent discrepancy is with respect to unemployment. But, in practice low-income laborers cannot afford to be unemployed. They use much of their time in job search (which may count as unemployment in government statistics but which does after all represent activity to increase income) and low-productivity, gathering activities. The neoclassical model accommodates that circumstance with a low real wage rate. The high wages in urban formal sector employment are due to the human capital that is required plus a premium to ensure stability of the labor force for the very high cost capital that is combined with that labor. The growth model has three main advantages: (1) it simplifies to focus on the key relationships; (2) it can accommodate simultaneity and thus capture

[1] That strategy is in the context of the Government of Rwanda's basic emphasis on commercialization and intensification as the twin pillars of accelerated agricultural growth and the commodity priorities delineated by the Rwandan Parliament.

complexities of resource transfers across sectors that make it more realistic than the growth accounting framework; and (3) it has a much more rigorous, internally-consistent framework than the growth accounting approach.

In fact, the two approaches give generally similar results. The neo-classical, three-sector model shows a larger growth in the demand for labor and hence in wage rates than implied in the growth-accounting framework approach. It also provides moderately higher growth rates for all sectors except agriculture, than do the estimates presented in the basic paper. Agriculture grows somewhat more slowly in the three-sector model because labor is pulled out of agriculture more rapidly than is the case in the basic paper, which does not allow for shift of factors of production across sectors. All these differences are largely due to the perfect mobility of factors of production.

The third paper in this set, entitled “Productivity-Increasing Rural Public Works – An Interim Approach to Poverty Reduction in Rwanda” (Mellor 2002b), accepts the employment growth numbers of the growth accounting framework. However, it starts from an assumption of substantial unemployment in the rural sector. That assumption reflects the disruptions of the past decade. It assumes an eleven-year, massive decline in unemployment due to agricultural growth as calculated in the basic paper. It then postulates a rural public works program that absorbs the remaining unemployed after five years of rural public works expansion. The rural public works scheme phases out over the next five years during which agricultural growth allows for the absorption of labor released from the discontinued rural public works program. The benefit of the rural public works is not only a much more rapid decline in poverty than would otherwise be possible, but an immense increase in rural capital. That increase is essential to the continued progress of the agricultural revolution set forth in the basic paper.

Four other papers are critical complements to this paper. Two are by Gunvant Desai (2002a and 2002b) who lays out the requisites for rapid growth in fertilizer use, assesses progress over the past two years, and a makes a set of recommendations. In the high-agricultural-growth scenario outlined by Desai, fertilizer accounts for 75 percent of incremental growth. The other two are by Frans Goossens (2002) who analyzes the needs for absorbing rapid growth in potato production and by Charles Crissman (2002) who assesses progress to date with respect to potato production and marketing and provides recommendations for action for both the short run and the long run. In Crissman’s high-agricultural-growth scenario, potato is the most responsive crop to fertilizer use and has the highest growth rate. Crissman, therefore, makes a strong case for improved potato marketing. Thus, these four papers deal with two critical components of the strategy to achieve high agricultural growth in Rwanda.

# 1. Introduction

Numerous studies show that growth reduces poverty. However, a substantial subset of such studies show that the structure of growth matters very much to poverty reduction. Some structures reduce poverty greatly, others hardly at all.

Early analysis by Ahluwalia (1978), and by Mellor and Desai (1985) shows that fluctuations in poverty in India were largely explained by fluctuations in the agricultural growth rate. Recent work completed separately by Timmer and Ravallion, analyze the relation between sectoral growth rates and poverty reduction over time and across geographic regions. Timmer (1997) shows that 85 percent of poverty reduction is attributable to agricultural growth. Ravallion and Datt (1996) show that rural growth and agricultural growth have a far greater impact on poverty reduction than does urban, industrial, or large-scale tertiary growth. These same studies show that there is a lag in the reduction of poverty from agricultural growth and that the impact on poverty of agricultural growth in the context of highly skewed land distribution is weak. Recently, there has been an international focus on absolute poverty. However, lifting large numbers of people out of poverty will occur by increasing the real incomes of those who earn their income largely from their labor. Thus reducing poverty is roughly synonymous with increasing employment and the wage rate.

Agricultural growth does generate substantial employment in agriculture. That is because the sector is so large, and despite the fact that agricultural growth must occur primarily through technological change. Land is important in agricultural production and the potentials for expanding the land area are typically very small. Only slow expansion occurs even under the best of circumstances. The technological change that relaxes the land constraint not only increases land productivity, but labor productivity as well. Hence, employment growth in agriculture grows much slower than production (Rao, 1975). Agriculture's impact on employment is much more through its indirect effects. The primary source of employment of low-income laborers is in the non-formal sector and the bulk of non-formal employment, in turn, is located in the rural sector.

This paper presents a three-sector mathematical model that is consistent with the results of earlier work that characterized the relationship between agriculture, the non-farm sector and economic and employment growth. It models the differential impact of acceleration in the agricultural growth rate on GDP and the demand for labor. The paper first describes the employment and GDP composition of the urban and rural sectors and the tradable and non-tradable sub-sectors within each. Collapsing the two non-tradable sectors (urban and rural) into one leaves a computable three-sector model. The paper then presents data on the share of each factor used in each sector's production as well as the average and marginal expenditure patterns of the recipients of the various factor shares. Focus is on differences in expenditure on the non-tradable sector.

Contributions to GDP and employment, as well as factor shares constitute the data required to analyze the differential impacts on employment produced by growth in agriculture versus the urban, tradable sector.

The model presented is based on neo-classical assumptions. That is, that markets work and provide optimal allocation of resources, that all resources are fully employed, that knowledge is perfect, and that adjustments to change in prices and resource quantity are instantaneous. It should be noted that while the principal economic problem of Rwanda is conveniently described as one of unemployment, the reality is somewhat different. In fact, only a small percentage of the labor force is actually unemployed. The problem is actually the low return to labor, particularly unskilled or semi-skilled labor. The labor market will tend to pay a higher wage in the more capital-intensive, tradable, urban sector than in the non-tradable sector partly because of higher skills demanded, but also to ensure a stable labor force to be combined with costly capital factors. The wage levels in the various sectors are, of course, linked.

Thus, the economic problem of low returns to unskilled labor will be ameliorated by demand that grows more rapidly than supply. Increase in the wage rate measures the improvement in the incomes of the so-called 'laboring class', in other words, those who have only one factor of production to offer – labor. The paper therefore compares the effect on the wage rate of growth in the agricultural and urban tradable sectors.

## 2. Model Conceptualization

A three-sector model has been constructed that clearly demonstrates the different impacts on employment generated by growth in the rural, tradable and the urban, tradable sectors. Demand for output from the two tradable sectors is not constrained by national income. They can export what is not consumed domestically. For those sectors, production is determined by the factors of production - land, labor, and capital - and by technological change. The growth of the third, so-called non-tradable, sector is constrained by domestic demand associated with expenditure by the two tradable sectors. The non-tradable sector cannot export its products because of their low quality and the high cost of transactions. Since the non-tradable sector employs the majority of Rwandans, the determinants of demand for the output of that sector is the prime determinant of growth in the demand for labor, of wage rates, and, hence, of income of the laboring class.

The model assumes three different production functions for each of the three sectors. In particular, it assumes that:

1. Land is important to agricultural production, and because of constraint in its supply, technological change is a major source of agricultural growth. Labor is also a major factor of production.
2. Urban tradables do not use land. Capital is the dominant factor of production. Labor is of modest importance.
3. The non-tradable sector is simplified to use only labor in its production.
4. Income to labor is the primary source of demand for the non-tradable sector.
5. Income to land largely accrues to farmers of modest income and serves as a secondary source of demand for non-tradables.[2]
6. Income to capital, including human capital, is spent on tradables.
7. Not all wage payments are considered as a return to labor. Wage payments in excess of the farm worker's wage are considered a return to capital (in particular, human capital) and are spent like other returns to capital on tradables.

[2] One could assume that land income had a quite different expenditure pattern to that of labor. For example, where it accrues to absentee landlords one might assume that it is spent like returns to capital. That would be consistent with analysis that shows that when land is highly unequally distributed, agricultural growth has little impact on poverty (Timmer, 1997).

Thus, the relevance of the model hinges on a large, dominantly rural, non-tradable sector that has a high factor share to labor and represents a major share of total employment; a tradable agriculture sector that spends a high proportion of its income on non-tradables; and, a tradable urban sector that has a low factor share to labor that is in turn the only source of its expenditure on non-tradables.

## 3. Data

Data presented in table 1 reveals that the Rwandan case largely fits the assumptions of the model discussed above. The rural sector is divided into a farm sub-sector (deemed tradable, also called the "agricultural sector") and a non-farm sub-sector (deemed non-tradable). The urban economy is divided into a formal or large-scale sector (deemed tradable) and a non-formal or small-scale sub-sector (deemed non-tradable). A rural economy in equilibrium will demonstrate rather little idle labor. Rather, the poor, in particular, will search for employment and engage in gathering activities that provide minimal income. At present, the major disruptions in the rural economy of Rwanda result in substantial open unemployment. Thus, a model that assumes no unemployment better describes the pre-genocide situation, or one a few years from now when the economy has moved closer to equilibrium. Mellor (2002b) describes a rural public works scheme that offers a strategy for removing current unemployment.

Despite the importance of the rural non-farm and the urban non-formal sector in employment generation, data collection underlying the national accounts does not facilitate a separation of the rural non-farm sector from agriculture or even the urban non-formal sector from the urban formal sector. So, while the key parameters offered in tables 1 and 2 are estimates, they represent the most educated adjustment of urban and rural GDP and employment shares, and sector factor shares.

**Table 1**

**Assumptions on the Share of GDP and Employment, and Factor Shares, by Sub-Sector**

| Sector | % of GDP | % of Employment | Labor Share | Capital Share | Land Share | Total |
|---|---|---|---|---|---|---|
| Rural | | | 58 | 10 | 32 | 100 |
| Tradable (farm) | 40 | 44 | | | | |
| Non-tradable (non-farm) | 25 | 46 | | | | |
| Subtotal | 65 | 90 | | | | |
| | | | | | | |
| Urban | | | 8 | 92 | 0 | 100 |
| Tradable (formal) | 32 | 5 | | | | |
| Non-tradable (non-formal) | 3 | 5 | | | | |
| Subtotal | 35 | 10 | | | | |
| | 100 | 100 | | | | |

[a] See appendix for explanations of these figures.

*Sources: Author's estimates and see appendix for discussion of sources.*

**Table 2**

**Summing of Assumed GDP, Employment and Factor Shares into Three Sectors, Rwanda**

| Sector | % GDP | % Employment | Labor Share | Capital Share | Land Share | Total |
|---|---|---|---|---|---|---|
| Rural Tradable (Agriculture) | 40 | 44 | 58 | 10 | 32 | 100 |
| Urban Tradable | 32 | 5 | 8 | 92 | 0 | 100 |
| Non-tradable | 28 | 51 | 100 | 0 | 0 | 100 |
| Total | 100 | 100 | | | | |

[a] See appendix for explanations of these figures.

*Sources: Author's estimates but also see appendix for notes on sources.*

**GDP Base Proportions**

Ministry of Finance and Economic Planning statistics report that 40 percent of GDP is generated in agriculture (Republic of Rwanda, 2000). The task therefore is to allocate the remaining 60 percent of GDP to the remaining three sectors.

Micro data for Rwanda collected by Michigan State University provide a basis for estimating the GDP in the rural non-farm sector. These pre-genocide data show 24 percent of farm gross income is spent off the farm (Loveridge, 1992). We presume that essentially all of off-farm spending of the agriculture sector would be spent on non-tradable, i.e. locally produced, goods. Twenty-four percent of a sector that constitutes 40 percent of the overall economy translates into 9.6 percent of GDP (40 * 0.24). In addition, we assume that marketing charges are 30 percent of the value of marketed output (Loveridge, 1992) and half of that is spent locally. This suggests that an additional 2.9 percent (0.30 * 9.6 * 0.5) of GDP may be attributed to the non-farm sector and bringing the running total to 12.5 percent (9.6 + 2.9). If the rural non-farm sector spends half its incremental income within that sector, that would provide a multiplier of two, totaling 25 percent of GDP in the rural non-farm sector.

With 65 percent of GDP attributed to the rural tradable and non-tradables sectors, we are left with an urban sector that contributes 35 percent of GDP. The formal sector is large-scale, capital-intensive, and derives income independent of the agriculture sector, and presumably at the margin from exports. Thus, urban tradable would include the export industries and the sectors directly serving those industries such as electric power, finance, insurance and the like. In effect, government would be seen as largely exogenous of agriculture and so it is included in the urban formal sector. In contrast, the urban non-tradable sector is comprised of labor-intensive, small-scale firms, which produce consumer goods that are sold exclusively to the domestic market.

We begin with an estimate that 32 percent of GDP may be attributed to the urban, tradable sector. In addition, we assume that 8 percent of urban income goes to labor (the rest is return to capital including human capital). As in the rural economy, we assume that half of urban incomes are spent on the urban non-tradable sector. Furthermore, as assume again that the urban non-tradable sector spends half of its own income within the sector. These assumptions suggest that the urban non-tradable sector represents three percent of GDP (32 * 0.08 * 0.5 * 2=2.6, rounded up to 3).

These estimates are entered in column 1 of table 1. The four sectors in table 1 are summed into the three sectors of table 2 by combining the two non-tradable sectors.

### Employment Base Proportions

The proportion of the labor force employed by the rural sector and furthermore, primarily employed by the agriculture sector, is reliable. These data have been extracted directly from government statistics and farm survey data that have received a wide vetting by foreign assistance organizations. Nevertheless, several adjustments must be made to supply the model with details for each of three sectors.

First, we assume that all families with more than 0.25 hectares are full-time farmers. Appealing to Mpyisi (2000) we estimate that therefore, that 40 percent of the labor force is engaged in the rural, tradable sector.[3] Increasing that estimate by 10 percent to 44 percent provides for inclusion of those working as agricultural laborers as their principal occupation (Mpyisi, 2000). That calculation provides 44 percent of the labor force as full-time farmers and farm laborers. This is a robust statistic for the purposes of this model.

Given the National Income accounts characterize approximately 90 percent of labor as rural, we assume that the remaining 46 percent of the labor force can be attributed to the rural non-farm sector (Republic of Rwanda, 2000).

The remaining ten percent of the labor force is divided equally between urban tradable and non-tradable.[4] Because of the small contribution of the urban sector to employment, the model results are not sensitive to even substantial departures from an even split of the urban labor force between the tradable and non-tradable sectors.

These estimates are entered in column two of table 1. Again, the four sectors in table 1 are summed into the three sectors of table 2 by combining the two non-tradable sectors. Note however that 90 percent of the non-tradable labor force is in the rural sector.

### Factor Shares

The constructed GDP and employment shares imply the share of labor in production. In the case of the urban sector where we assume there are only two factors of production, the residual factor share may be attributed to capital. In the case of the rural sector, as use slightly adjusted estimates from Clay (2001) of land's factor share, and again attribute the residual to capital.

---

[3] This is a simplification. In reality, some farmers with more then 0.25 hectares practice more extensive farming and do not contribute all their labor to agriculture. Conversely, on more intensive farming operations, farmers with less the 0.25 hectares may be full time farmers.

[4] An even split of employment between the two urban sectors is not pure convenience. It is in fact informed by the ratio of the share of employment to the share of GDP assumed in the rural non-tradable sector.

### Income and Price Elasticities

The income and price elasticities of demand for non-tradables of laborers and farmers are taken as 1.8 and –1.0, respectively. In a companion study of Egypt these elasticities were calculated as 1.5 and –1.25 (Mellor and Ranade, 2002). Data for these elasticities are not available for Rwanda. The estimate of income elasticity is extracted from household data for Egypt (IFPRI, 1997). Assuming that non-tradables are normal goods, the budget share of non-tradables would be lower and the elasticity higher for the relatively poorer Rwandans when compared with Egyptians.

## 4. Applications

We use our model, which is carefully outlined in the appendix, to consider three scenarios for Rwanda.

- The base case is to show the relationships from a high balanced growth rate, with rapid growth in both the agricultural sector and the urban tradable sector. All the other cases keep all the variables in the base case the same except for one that is specified.
- The second case shows the impact of radically slowing the agricultural growth rate by eliminating technological change in agriculture, all else kept the same.
- The third case radically slows the urban tradable sectors growth by reducing the capital formation rate to equal the labor force growth rate, else the same.

The key outputs from each of the scenarios are presented in table 3.

**Table 3**

**Key Findings from the Model**

| Scenario | GDP growth | Wage Rate growth (real) | Agriculture growth | Urban Tradable growth | Non-tradable growth |
|---|---|---|---|---|---|
| Base | 6.7 | 3.8 | 4.4 | 8.5 | 8.5 |
| II | 4.7 | 0.0 | 1.3 | 9.7 | 3.8 |
| III | 5.0 | 3.7 | 4.8 | 2.3 | 8.5 |

*Sources: Authors' calculations.*

In a neo-classical model, all resources are fully employed and move freely and instantly to equate marginal returns. To the extent that resources move less freely in Rwanda, the growth rate will be slowed. Thus, these growth rates should be considered upper bounds.

### Base Case – Rapid, Balanced Growth

The base case assumes: a 5 percent rate of technological change in agriculture, a 1 percent rate of growth of the cultivated area, an 8 percent rate of growth of the capital stock, a 2 percent rate of technological change in urban tradable sector, and labor force growth of 2.5 percent per year.

The 5 percent rate of technological change is consistent with doubling yields in 14 years. The fertilizer targets stated in Mellor (2002a) would double yields in much less time (Kelly et. al., 2001). Rwandan soils are unusually low in nutrients due to years of heavy cropping with little fertilizer use. Consequently, the soils are highly responsive to fertilizer application (Kelly et. al., 2000).

The World Bank's marshland intensification efforts alone provide a 0.5 percent annual increase for at least five years in cultivated area.[5] It is then assumed that the massive rural public works program planned (Mellor, 2002b) plus private activity acting on observation of the World Bank project will double the amount of marshland brought into highly intensive cultivation providing a total of a 1 percent rate of growth in cultivated area.

The 8 percent rate of growth of the capital stock is consistent with a roughly 20 percent investment rate. If, as commonly observed in developing countries, income is 2.5 times the capital stock, then an 8 percent rate of growth of the capital stock is consistent with a 20 percent (savings rate) of income. Foreign aid may provide much of that capital stock. This optimistic rate of growth for the capital stock protects against an understatement of the impact of non-agricultural growth.

The growth rates shown in the model are similar to those presented in Mellor (2002a). Notable, however, is the slower rate of agricultural growth and significantly higher growth in the urban tradable sector. This is explained in part by the simplifying assumptions of the neo-classical model and, in particular, by the accelerated growth in the real wage (or employment). In the model (as opposed to the estimates presented in Mellor (2002a), higher growth in the non-tradable and urban tradable sectors is fueled by the shift of labor out of agriculture.

In the three-sector model, the real wage rate grows at 3.8 percent per year in the context a rapid 2.5 percent rate of growth of the labor force. The real wage, and hence the per capita incomes of the laboring class double in 18 years. In order to compare these results with those presented in Mellor (2002a), we must translate wage growth into employment growth. To do so, we simply add the wage rate growth of 3.8 percent to the labor force growth of 2.5 percent for implied employment growth of 6.3 percent. With a total labor force in Rwanda of 3 million, 6.3 percent employment growth constitutes 189,000 new jobs per year, or more than twice as many new jobs as the Mellor (2002a) projects. The flexibility of labor markets assumed in the neoclassical case, allows for this increased absorption of jobs.

### Scenario II - Slowing Agricultural Growth

If one keeps all parameters the same except to eliminate the primary source of growth for agriculture (that is, to reduce technological change in agriculture to zero), then the rate of growth of GDP declines by 30 percent and real wage rate growth virtually ceases.[6] In this simulation, the rate of growth of agriculture declines to only 1.3 percent while the urban tradable sector increases its growth rate by 14 percent as resources from the technologically stagnant agricultural sector to the urban tradable sector. Because of the key linkage between agricultural and non-tradable sector growth, even higher tradable sector growth cannot overcome the devastating effect of slow agricultural growth. The non-tradable sector slows by 55 percent.

5 The World Bank program is technically one of intensification, not new lands, but the initial level of intensity is so low that it is a minor simplification to count this as new lands.

6 This result aligns with the empirical findings of Timmer (1997) and Ravallion and Datt (1996).

Two major points are made by comparing the base case with one of no technological change in agriculture.

* First, it is clear that agricultural growth is dependent on technological change. Without it, the land constraint dramatically reduces the productivity of other resources, which then move to other sectors.
* Second, agricultural growth is the dominant source of wage rate increases and therefore improvements in the incomes of the laboring class. If the sources of growth of agriculture are neglected, then the GDP growth rate slows only modestly but employment growth is virtually eliminated. A growth strategy that focuses only on the tradable urban sector can lead to moderately rapid growth of GDP, but the distribution of income will be highly inequitable.

#### Scenario III - Slowing Urban Tradable Growth

The last scenario returns to the assumptions of the base case, but assumes laggard capital stock growth of 2.5 percent. As a result, growth in the urban tradable sector declines by 73 percent from 8.5 percent to 2.3 percent. Furthermore, GDP growth drops from 6.7 percent to 5.0 percent. Notably, the growth of real wages remains rapid at 3.7 percent. This is a strategy that focuses only on agriculture and neglects capital stock growth necessary for the expansion of the tradable urban sector. Thus, even in Rwanda, with its unusually large agricultural sector, an 'agriculture-only' strategy provides good growth in employment and hence improves income distribution, but poor GDP growth.

#### Note on the Real Exchange Rate

Change in the real exchange rate is measured by the change in the wage rate and the price of non-tradables. Thus, a structure of growth that rapidly increases the demand for labor will cause a rise in the real exchange rate. That means that the cost of producing tradables rises and the exchange rate will have to depreciate in compensation. The domestic price of tradables will rise somewhat. That will push some consumption back towards the non-tradable sector. That effect is not measured in this model. The consequence is that the model slightly understates the rise in the demand for labor and hence the rise in the real exchange rate.

## 5. Conclusions

Agriculture and industry grow by quite different means. That is primarily because of very different factor shares in the two sectors. Technological change is the primary source of growth in agriculture; whereas an increased capital stock drives industry, or the so-called urban tradable sector. Slowing technological change in agriculture has a devastating effect on the return to labor. Slowing capital investment has a similarly devastating effect on growth of GDP.

The three scenarios show that while eliminating agricultural growth reduces the GDP growth rate by 30 percent, it virtually eliminates any improvement in incomes of the laboring class. It thus has a horrendous effect on income of labor, income distribution, and poverty. By contrast, reducing capital formation tempers the GDP growth rate by 25 percent, but only slightly reduces growth of the real wage.

The basic engine of growth in the two tradable sectors – agriculture and urban tradable – is quite different. Agriculture depends on technological change, which in a small-farmer agriculture scenario depends, in turn, on the provision of public goods. The urban tradable sector requires capital and hence the openness of capital markets. In both sectors, openness to international markets is potentially important. Trade provides a vent for surplus that would otherwise erode prices as output growth exceeded domestic demand growth. Employment depends largely on the non-tradable sector, the bulk of which is rural. A balanced growth strategy that provides for the needs of each of the sectors is clearly optimal.

The model results are based on the assumption that neo-classical conditions prevail. While no economy, including Rwanda, meets the neoclassical conditions perfectly, the model's basic dynamics, in other words the relative performance of sectors and the direction of their effect on employment, provides hugely useful guidance for policy. What stands out starkly is that technological change, broadly interpreted, drives agriculture sector growth and, in turn supports employment creation in the non-tradable sector.

Thus, growth does increase the income of the laboring class, but the structure of that growth, in other words, what sectors grow, is the dominant determinant of the participation of labor in the growth process. The structure of growth that benefits labor is one characterized by rapid growth in agriculture with a strong multiplier effect on the rural non-farm sector.

# Appendix: Model Presentation

### Sectors

The economy comprises three sectors: rural tradable, urban tradable and non-tradable. We assume that the economy is small and therefore must take the price of tradable goods as given.

The rural tradable sector displays a Cobb-Douglas production function with three inputs of production as follows:

$$A= t_a K_a^{\alpha} L_a^{\beta} Z^{\gamma} \qquad (1)$$

Where A is the output of the sector; Z, $K_a$ and $L_a$ are, respectively, land, capital and labor inputs; and $\alpha$, $\beta$ and $\gamma$ are parameters. The parameter $t_a$ measures technological change in the agricultural sector.

The urban tradable sector also displays Cobb-Douglas production with two inputs as follows:

$$Q = t_q K_q^{\varphi} L_q^{1-\varphi} \qquad (2)$$

Where Q is the output of the sector; $K_q$ and $L_q$ are respectively, capital and labor inputs; and $\varphi$ is a parameter. $t_q$ measures technological change.

The output (NT) in the Non-Tradable Sector is assumed to be proportional to the labor input as follows

$$NT = \delta L_{nt} \qquad (3)$$

Where, $L_{nt}$ is the labor input and $\delta$ is a parameter.

K and L are respectively the total capital and the total labor inputs exogenously given as follows:

$$L = L_a + L_q + L_{nt} \text{ and } K=K_a + K_q \qquad (4)$$

### Market Equilibrium Conditions

We assume that the four domestic markets in the economy are competitive and that the international market determines the price of urban and rural tradable goods.

The labor market equilibrium is determined by differentiating Equations (1), (2) and (3) by $L_a$ , $L_q$ and $L_{nt}$, and equating the marginal products of labor, respectively, as follows:

$$\beta t_a P_a K_a^{\alpha} r_a^{(\beta-1)} Z^{\gamma} L^{(\beta-1)} = P_{nt}\delta = W \qquad (5)$$

and

$$\beta t_a P_a K_a^{\alpha} r_a^{(\beta-1)} Z^{\gamma} L^{(\beta-1)} = (1- \varphi) t_q P_q K_q^{\varphi} r_q^{-\varphi} L^{-\varphi} \qquad (6)$$

where $r_a = L_a/L$, $r_q = L_q/L$, $P_a$ = price of agricultural goods, $P_q$ = price of industrial good and $P_{nt}$ = price of non-tradable.

Equation (5) shows that the wage rate is directly proportional to the price of non-tradables.

The capital market equilibrium is determined by differentiating Equations (1) and (2), and equating the marginal products of capital as follows:

$$\alpha t_a P_a K_a^{\alpha-1} r_a^{\beta} Z^{\gamma} L^{\beta} = \varphi t_q P_q K_q^{\varphi-1} r_q^{1-\varphi} L^{1-\varphi} \qquad (7)$$

The equilibrium in the non-tradable market is given by equating the supply of non-tradable goods and the demand for it by labor. Only the income to labor and land (as opposed to capital) is used to consume non-tradable goods. Note that in the agricultural sector the income of laborers is the sum of return from labor as well as land.

This may be represented as:

$$NT = C_{nt}\,(L_a + L_q + L_{nt}) + C_{nt}(\gamma/\beta)\eta L_a = \delta L_{nt} \qquad (8)$$

$$\delta r_{nt} = C_{nt}\,[1+(\gamma/\beta)\eta r_a]$$

where,

$r_{nt} = L_{nt}/L$, and $C_{nt}$ is the consumption per unit of labor for non-tradable goods, which is a function of income and prices as follows:

$(\delta C_{nt}/\delta W)(W/C_{nt}) = \eta$ = income elasticity of demand for non-tradable goods and
$(\delta C_{nt}/\delta P_{nt})(P_{nt}/C_{nt}) = \varepsilon$ = price elasticity of demand for non-tradable goods.

The second term in the second expression of eq. 8 captures the additional consumption of non-tradables by the agricultural laborers from the income from land.

### Comparative Statics

We will now use the model to study the effects of various exogenous variables like the total capital stock and labor force, technological changes in the agriculture, industry and non-tradables on endogenous variables such as $K_a$, $K_q$, $r_a$, $r_q$, $r_{nt}$, $P_{nt}$ and W. In order to do this we logarithmically differentiate equations (5), (6), (7) and (8) with various exogenous variables. Differentiating these equations with respect to the technological change in the agricultural sector $t_a$ and after rearranging the terms we get:

$$\alpha(\delta K_a/\delta t_a)(t_a/K_a)+(\beta-1)(\delta r_a/\delta t_a)(t_a/r_a) - (\delta P_{nt}/\delta t_a)(t_a/P_{nt}) = -1 \qquad (9)$$

$$[\alpha + \varphi(K_a/K_q)](\delta K_a/\delta t_a)(t_a/K_a) + (\beta-1)(\delta r_a/\delta t_a)(t_a/r_a) + \varphi(\delta r_q/\delta t_a)(t_a/r_a) = -1 \qquad (10)$$

$$[-(1-\alpha) - (1-\varphi)(K_a/K_q)](\delta K_a/\delta t_a)(t_a/K_a) + \beta(\delta r_a/\delta t_a)(t_a/r_a) - (1-\varphi)(\delta r_q/\delta t_a)(t_a/r_a) = -1 \qquad (11)$$

$$-(r_a/r_{nt})(\delta r_a/\delta t_a)(t_a/r_a) - (r_q/r_{nt})(\delta r_q/\delta t_a)(t_a/r_a) - (\eta+\varepsilon)(\delta P_{nt}/\delta t_a)(t_a/P_{nt}) = 0 \qquad (12)$$

The changes in $K_q$, W and $r_{nt}$ can be found by using the following equations:

$$(\delta K_q/\delta t_a)(t_a/K_q) = -(\delta K_a/\delta t_a)(t_a/K_a)(K_a/K_q) \qquad (13)$$

$$(\delta W/\delta t_a)(t_a/W) = (\delta P_{nt}/\delta t_a)(t_a/P_{nt}) \qquad (14)$$

$$\delta r_{nt}/\delta t_a = -\delta r_a/\delta t_a - \delta r_q/\delta t_a \qquad (15)$$

The above equations can be solved simultaneously for the changes in 7 endogenous variables, namely, $K_a$, $K_q$, $r_a$, $r_q$, $r_{nt}$, W and $P_{nt}$ and the values can be found in terms of the parameters and exogenous variables. The set of solutions are the percentage changes in the values of endogenous variables with respect to the percentage changes in different exogenous changes and are as follows:

| **Endogenous Variables** | **Solutions** |
|---|---|
| Where, | |
| $\Delta=$ | $(\eta+\varepsilon)\varphi(1-\alpha-\beta)+(r_a/r_{nt})(\alpha-\varphi)$ $-(r_q/r_{nt})[(1-\alpha-\beta)+((1-\varphi-\beta)(K_a/K_q)]$ and |
| $R=$ | $r_a(\gamma/\beta)\eta/[1+r_a(\gamma/\beta)\eta]$ |
| **CHANGE IN CAPITAL STOCK (K)** | |
| $K_a$ | $(r_q/r_{nt})(K/K_q)(-1+\varphi+\beta)/\Delta$ |
| $K_q$ | $K/K_q[1-(r_q/r_{nt})(K_a/K_q)(-1+\varphi+\beta)/\Delta]$ |
| $r_a$ | $-(r_q/r_{nt})(\alpha-\varphi)/\Delta$ |
| $r_q$ | $[(\eta+\varepsilon)(1-\alpha-\beta)\varphi(K/K_q)+(R/r_{nt})(\alpha-\varphi)/\Delta$ |
| $P_{nt}$&W | $(r_q/r_{nt})\varphi(-1+\alpha+\beta)(K/K_q)/\Delta$ |
| $r_{nt}$ | $(\eta+\varepsilon)\varphi(r_q/r_{nt})(K/K_q)(-1+\alpha+\beta)/\Delta$ |
| **TECHNOLOGICAL CHANGE IN AGRICULTURE ($t_a$)** | |
| $K_a$ | $[(\eta+\varepsilon)\varphi - R/r_{nt} - r_q/r_{nt}]/\Delta$ |

| | |
|---|---|
| $K_q$ | $-[(\eta+\varepsilon)\varphi - r_a/r_{nt} - r_q/r_{nt}](K_a/K_q)/\Delta$ |
| $r_a$ | $[(\eta+\varepsilon)\varphi - (r_q/r_{nt})(K/K_q)]/\Delta$ |
| $r_q$ | $-[(\eta+\varepsilon)\varphi(K_a/K_q) - (R/r_{nt})(K/K_q)]/\Delta$ |
| $P_{nt}$&W | $-\varphi[(R/r_{nt}) - (r_q/r_{nt})(K_a/K_q)]/\Delta$ |
| $r_{nt}$ | $-(\eta+\varepsilon)\varphi[(R/r_{nt}) - (r_q/r_{nt})(K_a/K_q)]/\Delta$ |

**TECHNOLOGICAL CHANGE IN URBAN TRADABLES ($t_q$)**

| | |
|---|---|
| $K_a$ | $[(\eta+\varepsilon)(\beta-1)+R/r_{nt} + r_q/r_{nt}]/\Delta$ |
| $K_q$ | $-[(\eta+\varepsilon)(\beta-1)+R/r_{nt} + r_q/r_{nt}](K_a/K_q)/\Delta$ |
| $r_a$ | $-(\eta+\varepsilon)\alpha + (r_q/r_{nt})(K/K_q)/\Delta$ |
| $r_q$ | $\{(\eta+\varepsilon)[(1-\alpha-\beta)-(\beta-1)(K_a/K_q)]-(R/r_{nt})(K/K_q)\}/\Delta$ |
| $P_{nt}$& W | $[(R/r_q)\alpha-(r_q/r_{nt})(1-\alpha-\beta)+(\beta-1)(K_a/K_q)(r_q/r_{nt})]/\Delta$ |
| $r_{nt}$ | $(\eta+\varepsilon)[\alpha(R/r_q) - (1-\alpha-\beta)(r_q/r_{nt}) + (\beta-1)(K_a/K_q)(r_q/r_{nt})]/\Delta$ |

**LABOR FORCE GROWTH (L)**

| | |
|---|---|
| $K_a$ | $(1-\beta-\varphi)[(R/r_{nt}) + (r_q/r_{nt})]]/\Delta$ |
| $r_a$ | $[-(n+\varepsilon)\varphi(1-\alpha-\beta)+(r_q/r_{nt})(1-\alpha-\beta)(K/K_q)]/\Delta$ |
| $r_q$ | $[-(R/r_{nt})(1-\alpha-\beta)(K/K_q) + (\eta+\varepsilon)\varphi(1-\alpha-\beta)]/\Delta$ |
| $P_{nt}$ & W | $[(R/r_{nt)+}(r_q/r_{nt})](1-\alpha-\beta)\varphi)/\Delta$ |
| $r_{nt}$ | $(n+\varepsilon)\varphi(1-\alpha-\beta)[(R/r_{nt})-(r_q/r_{nt})]/\Delta$ |

**TECHNOLOGICAL CHANGE IN NON-TRADABLE SECTOR (**d)

| | |
|---|---|
| $K_a$ | $(1-\beta-\varphi)(1+\varepsilon)/\Delta$ |
| $r_a$ | $(1+\varepsilon)(\alpha-\varphi)/\Delta$ |
| $r_q$ | $(1+\varepsilon)[(-1+\alpha+\beta)+(\beta+\varphi-1)(K/K_q)]/\Delta$ |

$P_{nt}$ $\{-(R/r_{nt})(\alpha-\varphi)+(r_q/r_{nt})[(1-\alpha-\beta)+(1-\varphi-\beta)(K_a/K_q)]$
$-(1-\eta)\varphi(-1+\alpha+\beta)\}/\Delta$

$r_{nt}$ $\{-(1+\varepsilon)(\alpha-\varphi)(r_q/r_{nt})-(R/r_{nt})(1+\varepsilon)[(-1+\alpha+\beta)+(\beta+\varphi-1)(K/K_q)]\}/\Delta$

W $1+\{-(R/r_{nt})(\alpha-\varphi)+(r_q/r_{nt})[(1-\alpha-\beta)+(1-\varphi-\beta)(K_a/K_q)]$
$-(1-\eta)\varphi(-1+\alpha+\beta)\}/\Delta$

In order to study the impact of the exogenous variables on the endogenous variables over time we combine all of the changes in the exogenous variables. The period for such an analysis is one year. The growth rates of endogenous variables are percent per year and are derivatives of time. They are estimated by plugging in the growth rates of exogenous variables in the combined equations. Such growth rates are then compounded to estimate effects for longer period. During the analysis we assume that the parameters, such as, the factors shares, income and price elasticities do not change.

## References


Ahluwalia, Montek S. (1978). "Rural Poverty and agricultural performance in India," *Journal of Development Studies*, 14: 298-323.

Clay, Dan et. al. (2001) *Input Use and Conservation Investments Among Farm Households in Rwanda, Patterns and Determinants,* Unpublished manuscript, Michigan State University, East Lansing.

Crissman, Charles (2002) "A Proposal for a Rwanda Potato Sector Development Program" Agricultural Policy Development Project, Research Report No. 17, Bethesda, MD: Abt Associates Inc.

Desai, Gunvant M. (2002a) "Sustainable Rapid Growth of Fertiliser Use in Rwanda: a Strategy and an Action Plan" in *Fertiliser Use and Marketing Policy Workshop Proceedings*, Agricultural Policy Development Project, Research Report No. 10, Bethesda, MD: Abt Associates Inc.

Desai, Gunvant M. (2002b) "Key Issues In Achieving Sustainable Rapid Growth Of Fertilizer Use In Rwanda" Agricultural Policy Development Project, Research Report No. 12, Bethesda, MD: Abt Associates Inc.

Goossens, Frans (2002) "Potato Marketing in Rwanda" Agricultural Policy Development Project, Research Report No. 12, Bethesda, MD: Abt Associates Inc.

IFPRI (1997) "Egypt Integrated Household Survey" Washington, DC: International Food Policy Research Institute.

Kelly, V. et al. (2002). "Fertiliser Consumption in Rwanda: Past Trends, Future Potential, and Determinants," in *Fertiliser Use and Marketing Policy Workshop Proceedings*, Agricultural Policy Development Project, Research Report No. 10, Bethesda, MD: Abt Associates Inc.

Loveridge, Scott (1992) "Sources of Agricultural Household Revenue, Exports, and Their Impact on Food Availability in Rural Rwanda" July, Kigali, Rwanda: Ministry of Agriculture and Livestock, Division of Agricultural Statistics.

Mellor, John W. and G. M. Desai. (1985) *Agricultural Change and Rural Poverty*, Baltimore, MD: Johns Hopkins University Press.

Mellor, John W. (2002a) "How Much Employment Can Rapid Agricultural Growth Generate? – Sectoral Policies for Maximum Impact in Rwanda," Agricultural Policy Development Project, Research Report No. 13, Bethesda, MD: Abt Associates Inc.

_________. (2002b) "Productivity-Increasing Rural Public Works – An Interim Approach to Poverty Reduction in Rwanda" Agricultural Policy Development Project, Research Report No. 15, Bethesda, MD: Abt Associates Inc.

_________ and C. Ranade (2002) "Modeling Egyptian Employment with a Three-Sector Model – Agriculture, Non-Tradables, and Urban Tradables," Impact Assessment Series, Agricultural Policy Reform Project, Bethesda, MD: Abt Associates Inc.

Mpyisi, Edson, et. al. (2000) "Food Security Survey Phase I: Agricultural Production and Land Use Season A," Kigali, Rwanda: Ministry of Agriculture, Animal Resources, and Forestry.

Rao, C.H.H. (1975) *Technological Change and Distribution of Gains in Indian Agriculture*, Delhi: Macmillan

Ravallion, M. and Guarav Datt, (1996) "How Important to India's Poor is the Sectoral Composition of Economic Growth," *The World Bank Economic Review*, 10(1).

Republic of Rwanda (2000) "Rwanda Development Indicators 2000," July, No. 3, Kigali, Rwanda: Ministry of Finance and Economic Planning, Department of Statistics.

Timmer, C. Peter. (1997) "How Well do the Poor Connect to the Growth Process?" CAER Discussion Paper No. 178, December, Cambridge, MA: Harvard Institute for International Development.